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ABSTRACT

Attached solar greenhouses are relatively inexpensive and easy to build; they can provide additional heat to homes all winter as well as fresh vegetables and flowers. This bulletin: (1) describes the characteristics of a solar greenhouse; (2) provides a checklist of five items to consider before building a solar greenhouse; (3) describes the four basic solar greenhouse components (footings, framing, glazing, and heat storage); and (4) lists step-by-step procedures for the construction of a typical greenhouse. (JN)

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INFORMATION
U.S. DEPARTMENT OF ENERGY
CONSERVATION AND RENEWABLE ENERGY INQUIRY AND REFERRAL SERVICE

ED270292

# Build A Solar Greenhouse*

Attached solar greenhouses are very popular—in fact, they are springing up all over the United States. They are relatively inexpensive and easy to build, and can provide additional heat to homes all winter as well as fresh vegetables and flowers.

## What is a Solar Greenhouse?

A solar greenhouse is similar to a conventional greenhouse, except that (1) mass is added for heat storage, (2) double glazing is used (two layers of glass or plastic to reduce heat loss to one-half that of a single layer), and (3) the north side is attached to the house.

All solar energy systems collect energy, store it, then transfer it to a point of use, like a house. The solar greenhouse collects the sun's energy through the south-facing glazing, stores it in such things as barrels of water, adobe or masonry walls, floors, and/or growing plant beds, and in turn transfers it to the house to provide supplemental wintertime heat.

## Should You Build One?

Before you lift a hammer or spend a single penny, go over the following checklist:

1. Look at the south side of your house. Does it face within 30° of true south? Does the winter sun shine on it with comparatively little obstruction from trees, fences neighboring buildings, etc.?
2. Would an attached solar greenhouse present a pleasing appearance?
3. Could a solar greenhouse be attached to the south side of your house and communicate with it through a door, window, or other opening? (If not, can you make an opening in the wall of the house at the top and at the bottom to convey air between the greenhouse and the house?)
4. Do you—or a willing family member, or friend—have basic carpentry skills? You do not have to be a professional, but you need to be able to make simple measurements, hammer and saw straight, and know how to work slowly and carefully. With average home handyman abilities, some hard work, and patience, you will be able to construct a solar greenhouse that is a work of art.
5. Are you willing and able to invest a minimum of $500 in the materials you will need to do the job properly? If so, and if you have a green thumb, every year your greenhouse should make it possible for you to produce about 40 pounds of tomatoes, 25 pounds of cucumbers, 75 heads of lettuce, some onions, radishes, herbs, and other vegetables. This way you could save about $100 in your annual salad budget and perhaps recover the complete cost in a few years. As an additional bonus, your solar greenhouse should save you money on your heating bills—how much depends on the size of your greenhouse relative to the size of your home, how well it is designed and built, and a variety of other factors.

## Where do You Begin?

If you have answered "yes" to all of these questions, get moving! Your beginning step is to make a decision about the basic design of your greenhouse. Solar greenhouses are like fingerprints—no two are identical (unless you buy a mass-produced kit). This booklet describes simple designs from the ground up so you can select the features you like best about each and combine them to put your own personalized greenhouse together. The important thing is to be very careful to stick to the precise measurements and specifications provided. If correctly followed, the result will be a solar greenhouse structure which complies with the requirements of most building codes.

Now, let's take a look at each of the four basic components of any solar greenhouse: footings, framing, glazing, and heat storage. After that, we'll go through a step-by-step procedure for the construction of a typical greenhouse which can be used as a guide for the construction of your own greenhouse.

## Footings

A footing in the ground is intended to make sure that the weight of the greenhouse—along with any superimposed weight load, such as

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snow or wind—is evenly distributed. A typical solar greenhouse weighs very little. However, wind could be troublesome when it is an upward force that could conceivably shake your greenhouse loose if you leave the door open. Anchoring in a good solid footing will prevent both the problems of weight distribution and the vagaries of the wind. Moreover, a good footing below the frost line will prevent winter frost from heaving the structure.

You can use a wooden footing if you desire, as long as it is anchored securely in the ground. Why not use concrete? Build your greenhouse to last—and leave something for archeologists to ponder 500 years from now. Here is one footing option:

Figure 1 depicts a conventional footing that conforms to the Uniform Building Code. The footing and stem wall insulation should extend at least 24 inches below the ground on the outside of the masonry. This assures that the heat transmitted through the glazing is soaked up in the floor and not lost to the ground outside.

## Framing

Methods of framing a solar greenhouse vary, depending on the type of glazing you plan to use, the weather in your area, and the way in which the greenhouse will communicate with your house.

The type of glazing you choose will determine the frame spacing you will need to construct; refer to the section on glazing for the choices available.

A greenhouse that has a vertical south face will be cooler in the summer. A vertical wall will collect 25 percent less solar energy from October through April than a wall built at a 60° angle, but the same wall will conduct only half as much heat energy in the summer months. A vertical wall also allows for more interior space, and is easier to insulate against nighttime heat loss.

You will have to make some compromises in deciding upon the right design for your location and purposes. You may want maximum winter performance, which means an angled south wall. In this case the summer heat can be reduced only by an additional investment in some kind of shading device, swamp cooler, or powered exhaust fan.

Good ventilation is extremely important for proper temperature control. A vent should promote the natural flow of air from a low entry to a high exit across the greenhouse. The vent placement should be such that the prevailing summer breeze pushes right through the vents. When you design the vents, try to recall the direction the summer wind comes from most of the time in your location. The low vent should face the prevailing wind.

Figures 3, 4, 5, and 6 illustrate framing designs you might consider. Use these designs as guides. Select the best features of each, and then make a sketch of your own personal design to be sure you don't forget anything. Use cross-hatched graph paper and an architectural scale with a straightedge to draw where each board, door, window, etc., will be placed. Remember, a 2 x 4 is really 1½ inches x 3½ inches; a 2 x 6 is really 1½ inches x 5½ inches, and so on.

A word about finishing: paint all components that will be in contact with water or soil with copper naphthenate; paint all framing a light color before the glazing is applied. Use latex base paint.

## Glazing

No glazing material is best. Every product has advantages and disadvantages. The type you choose is determined by appearance, cost, and how you intend to use your greenhouse. An optically clear product like glass will let direct rays through, while a plastic like fiberglass will scatter the rays into what is known as a diffuse pattern. This diffuse lighting is preferable for plant growth.

Glass is optically clear, can withstand high temperatures, and can be heat-treated to withstand impact. If you choose to use glass, one convenient technique is to design your framing for doubleglazed patio

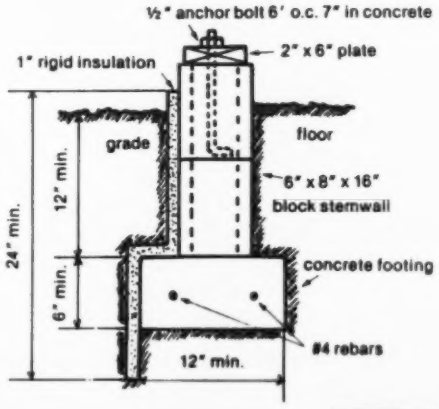
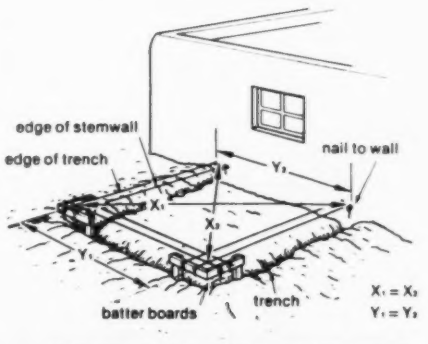



**Figure 1**




Make sure your walls and footings are really square.

**Figure 2**

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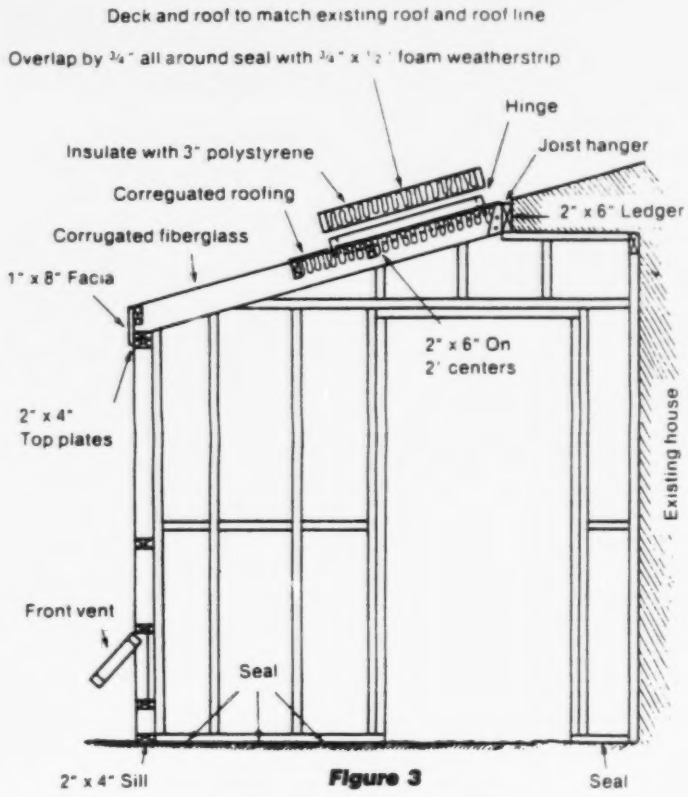



**Figure 3**

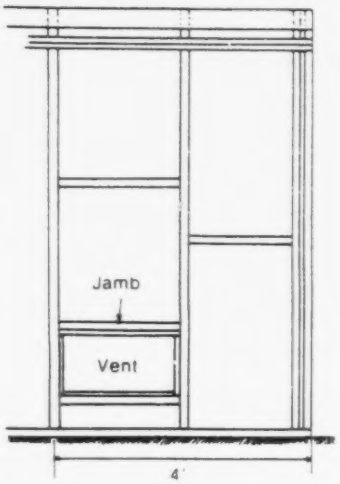
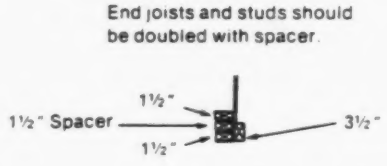



**Figure 4**



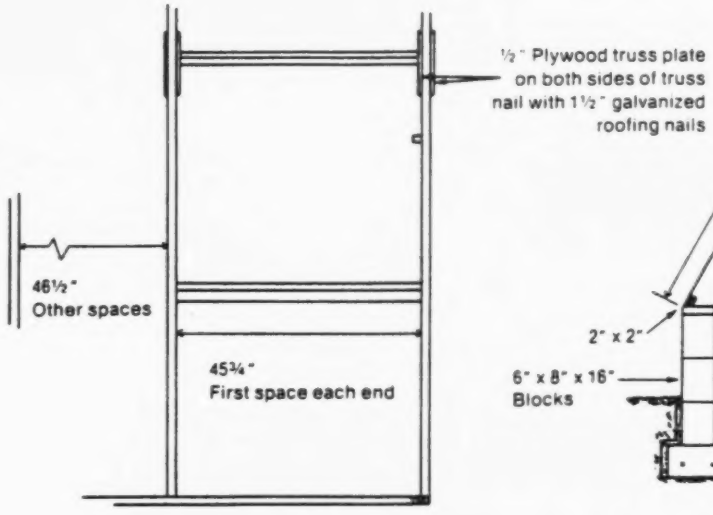




**Figure 5**

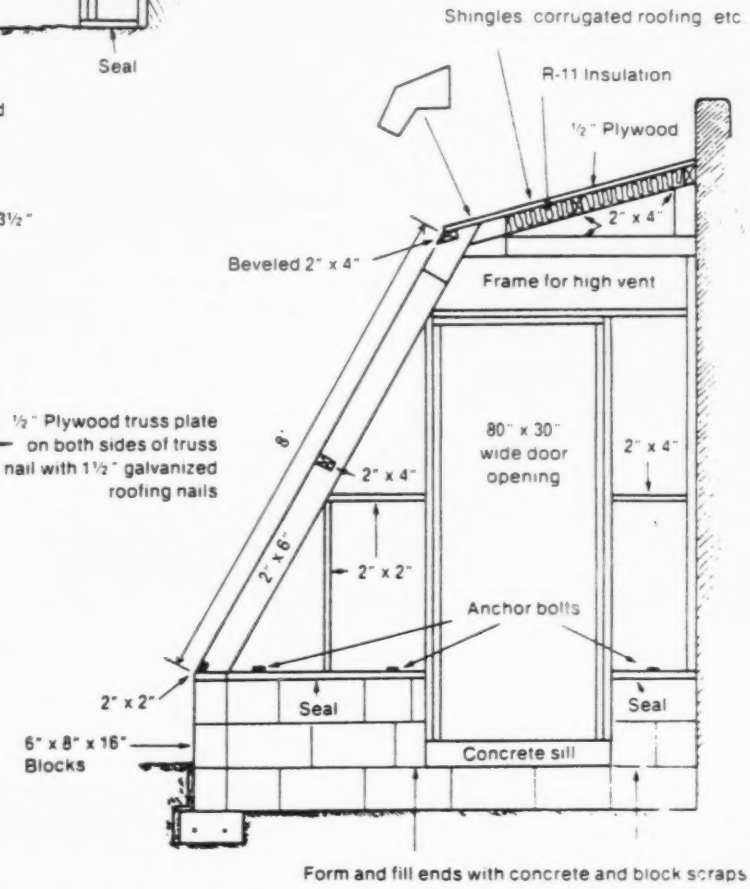



**Figure 6**



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door replacement panels. They come in 28-inch x 76-inch, 34-inch x 76-inch, 46-inch x 76-inch, 34-inch x 92-inch, 46-inch x 92-inch, and other sizes. Check your glass supplier for prices and availability. Be sure to pinch off the vent in the panel before installation since this stabilizes the air pressure. Use a generous amount of silicone sealant around all sides of the window.

There is an optically clear, 7-mil laminated plastic available which is very tough and has been successfully tested for long-term weatherability. It comes in a 4-foot-wide roll. All other plastics, like fiberglass, are translucent — they let the light in but you can't see through them. If you prefer plastic, be sure the product you choose transmits at least 85 percent of the solar spectrum and is ultra-violet stabilized. Your dealer can help you with this selection.

A very convenient but expensive material is a cellular vinyl or polycarbonate which comes in a very strong, light-weight, and double-glazed 4-foot-wide sheet. You can nail it with self sealing nails after you thoroughly seal the cells with silicone. Use nothing but silicone, and be sure that penetration is at least one-half-inch on all cells.

The most important aspect of the glazing process is to be sure to seal every joint. Your greenhouse must be airtight. Use good quality sealant-at least a polymer and preferably silicone.

## Heat Storage

Without a lot of dense materials (such as adobe, cement block, water containers, etc.), the air temperature inside your greenhouse could vary considerably from day to night. The addition of mass will tend to stabilize greenhouse temperatures.

When you have completed your greenhouse, install as many dark-colored (black, brown, or green) 55-gallon drums as your space will comfortably allow. Fill them with water, add one-fourth cup of sodium dichromate as a corrosion inhibitor in each drum, cover them, and use them as supports for the benches you will construct on which you will place planting boxes for vegetables, flowers, and so on. The growing beds, insulated floor, massive north wall, and water-filled drums should provide the heat storage you need. To make sure the heat stored in the greenhouse is transferred into your house, install a thermostatically-controlled window fan to blow warm air into the house during the winter.

## Building a Typical Solar Greenhouse: Step-by-Step Instructions

The following instructions will give you an idea of the steps necessary for the successful construction of an attached solar greenhouse. The instructions are based on a 'typical' greenhouse design which may or may not coincide with the design you have decided upon. Even if you have selected a different style of footing, framing, and/or glazing, these instructions should serve as a helpful guide. Read them–then vary the steps in accordance with your particular situation.

Step 1. Lay out the footing and stem wall using batter boards and strings as shown in Figure 2. The strings define the edge of the footing trench and the stem wall.

Step 2. Dig a trench that is 12 inches wide and 18 inches deep.

Step 3. Place ½-inch rebar 3 inches from the bottom. Block it in place with flat stones or stakes with the rebar wired onto the stakes.

Step 4. Pour concrete into the trench at least 6 inches deep. Use a level and trowel to form a smooth level top surface.

Step 5. When the footing is firm, lay the stem wall, using mortar mix for the joints: stagger the vertical joints.

Step 6. Every 4 feet, fill the core with concrete or mortar mix. Fill the other cores with vermiculite insulation or tamped dirt if most of the stem is below grade. Leave 4 inches of each core unfilled and then pour in concrete or mortar. Don't forget to install the anchor bolts for the sill plate.

Step 7. Place a minimum of 1-inch-thick polystyrene bead board 24 inches into the ground on the outside of the stem wall and footing. This assures that the heat transmitted through the glazing is soaked up in the floor and not lost to the ground outside. The foundation and stem wall should now be complete.

Step 8. Place the front sill plate in position by indenting each anchor bolt location and drilling holes to slide the plate in place.

Step 9. Using the sill plate as the first member, lay out the south face on a level spot and nail the sill, studs, and headers with 16-penny nails, as shown below.

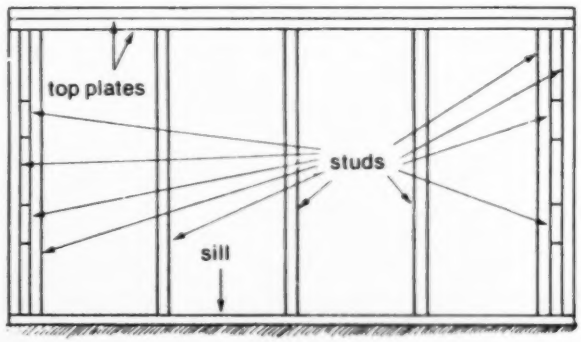


*Figure 7*



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Step 10. Place the front face in position with strips of insulation, weatherstripping, or caulk between the sill and stem wall to cut off any possible air leaks. Brace to the desired upright angle.

Step 11. Cut the side sills, permanently seal, and put into position.

Step 12. Affix a 2 x 6 ledger on the house. You can nail through the existing siding into the house studs; use lead anchors and lag screws; or whatever means are appropriate for your house (see Figure 3).

Step 13. Place roof joist hangers on the ledger in their proper locations.

Step 14. Cut and nail 2 x 6 roof joists to fit the angle of the roof, the joist hanger, and the front face. If the house and south face are not parallel, custom-fit each joist.

Step 15. Cut the end members to fit the roof and front face contour, door, and vents. The framing is now complete.

Step 16. Let's assume that the roof is made of corrugated steel. The safest method for avoiding roof air leaks is to caulk all seams and pop-rivet the sections into a continuous strip. You can also use an abundance of lead-headed roofing nails to put the roof in place.

Step 17. Insulate between the joists with roll fiberglass insulation (6-inch fiberglass has a heat resistance rating of R-19), stapled in place with no folds or tucks.

Step 18. Finish the interior ceiling with masonite, paneling, or green waterproof sheetrock. Seal and nail rigid corrugated fiberglass to roof portions that are not opaque. (A polyethylene vapor barrier could be installed if desired.)

Step 19. Add the front fascia plate when the roof is complete.

Step 20. Paint the entire frame with a light-colored latex base covering.

Step 21. Glazing is next. Nail Tedlar-coated rigid fiberglass on the inside and outside of the studs. Be sure to generously apply caulking to the studs before attaching each sheet. Trim the inside and outside seams with pre-painted batten strips. Don't skimp on the nails for these operations.

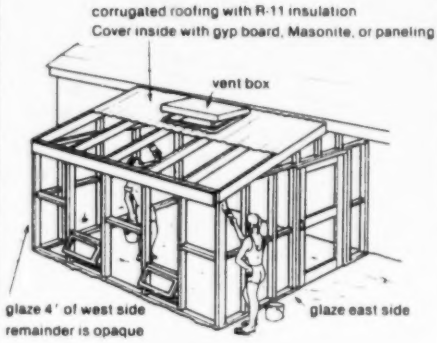
corrugated roofing with R-11 insulation
Cover inside with gyp board, Masonite, or paneling
vent box
glaze 4' of west side
remainder is opaque
glaze east side

*Figure 8*

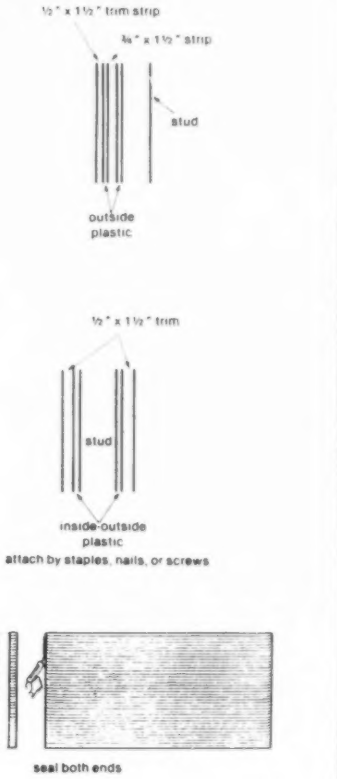


*Figure 9*

Step 22. Construct the vents and doors to fit the openings you provided. The main key is the provision of strong corners. Test the hinges by simulating the movement of the device before notching or attaching the hinges. Weatherstrip all moving joints.

Step 23. Place dark-colored 55-gallon drums inside the greenhouse (as discussed in the section on Heat Storage). If you can comfortably fit more than five drums inside the greenhouse, add as many as you desire.

Step 24. Acquire a fan and 110-volt thermostat that can be set to 90°F. Wire the thermostat into the lead and plug into a socket. The fan will blow hot air into your house when the greenhouse reaches 90°F during the winter. You should also get a minimax thermometer which will tell you the temperature swings within your greenhouse. Adjust the house blower so the greenhouse temperature does not rise above 95°F and harm your plants. Each installation requires individual experimentation to achieve optimum results.



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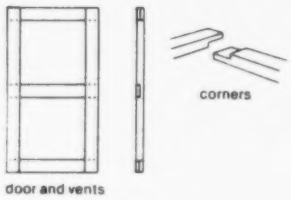


*Figure 10*

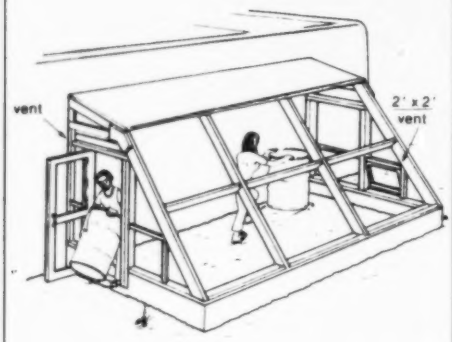


*Figure 11*

## For Further Details...

Further information on solar greenhouses including a bibliography and list of plans is available from the Conservation and Renewable Energy Inquiry and Referral Service. If you have any questions regarding the material in this fact sheet contact the New Mexico Solar Energy Institute, Box 3-Sol, Las Cruces, NM 88003; (505) 646-1846, (800) 432-6781 (New Mexico only).



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